"Climate change, physical-biological coupling, and the resource mismatch hypothesis for plankton and fish"

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Conclusions

- All successful studies on climate have involved long time series with coverage during all seasons…
- …with targeted studies of important processes to understand dynamics.
- Nearshore as well as offshore zones need to be studied
- Winter and the winter-spring transition are poorly understood and important seasons.
- New tools (instruments) are needed to make necessary measurements.
- Research organizations should make use of their field stations to collect these time series in their backyards.


Muskegon Field Station

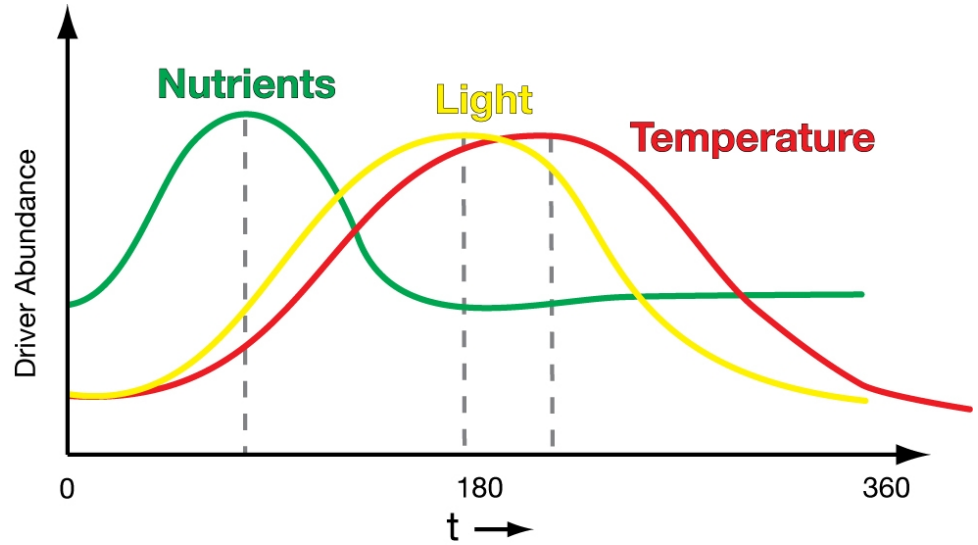
Ecologically relevant physical and chemical variables affected by climate change

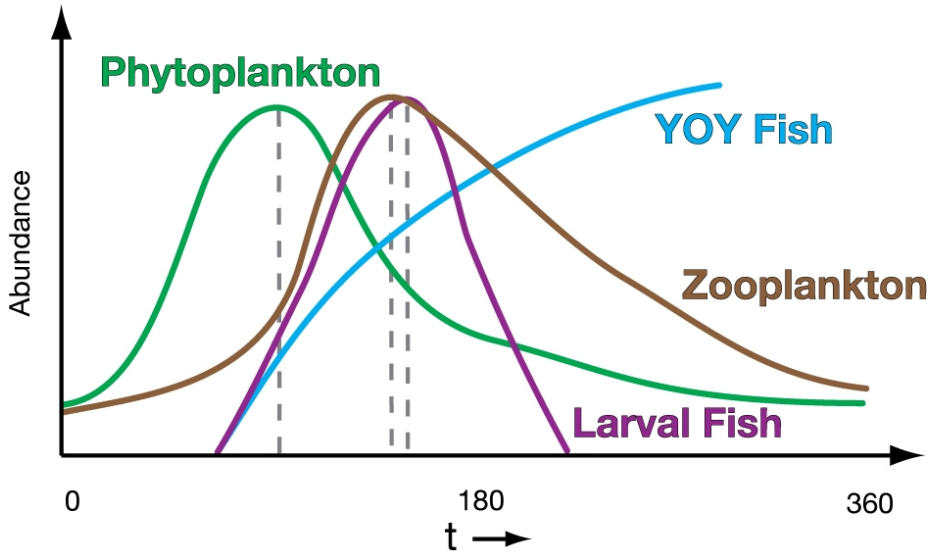
Important Eco Variable	**Climate-related Driver**
Onset & duration of ice cover	Temperature, wind
Onset & duration of thermal stratification	Temperature, wind
Turbulent dissipation rate	Wind, ice, stratification
Turbidity	Turbulent dissipation rate
Nutrient loading timing and intensity	Rainfall & snow melt patterns
Hypolimnetic O_2	Temperature, stratification, nutrient loading
Light (including ultraviolet radiation)	Cloudiness, ice cover, turbidity, CDOM, rainfall patterns

Temperature affects Ecophysiolgy of organisms

- A lot of processes like respiration have a $Q_{10} \approx 2$
- P/B increases with temperature within a certain range and drops off thereafter depending on species
- Temperature tolerance varies among species.

Resources and Predator-Prey Mismatch Hypothesis (MMH) in a Hypothetical Large Lake (aka “the phenology story”)





Larval Recruitment

Concepts:

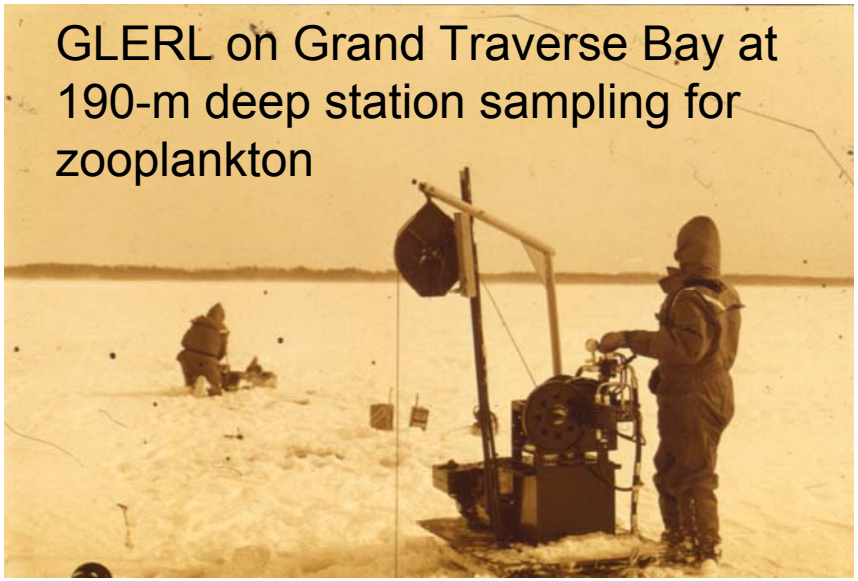
- The critical period hypothesis (Hjort 1914)
- “Match/Mismatch” Hypothesis (Cushing 1969)

Larval and YOY Alewife

Whitefish & Ice Recruitment Story

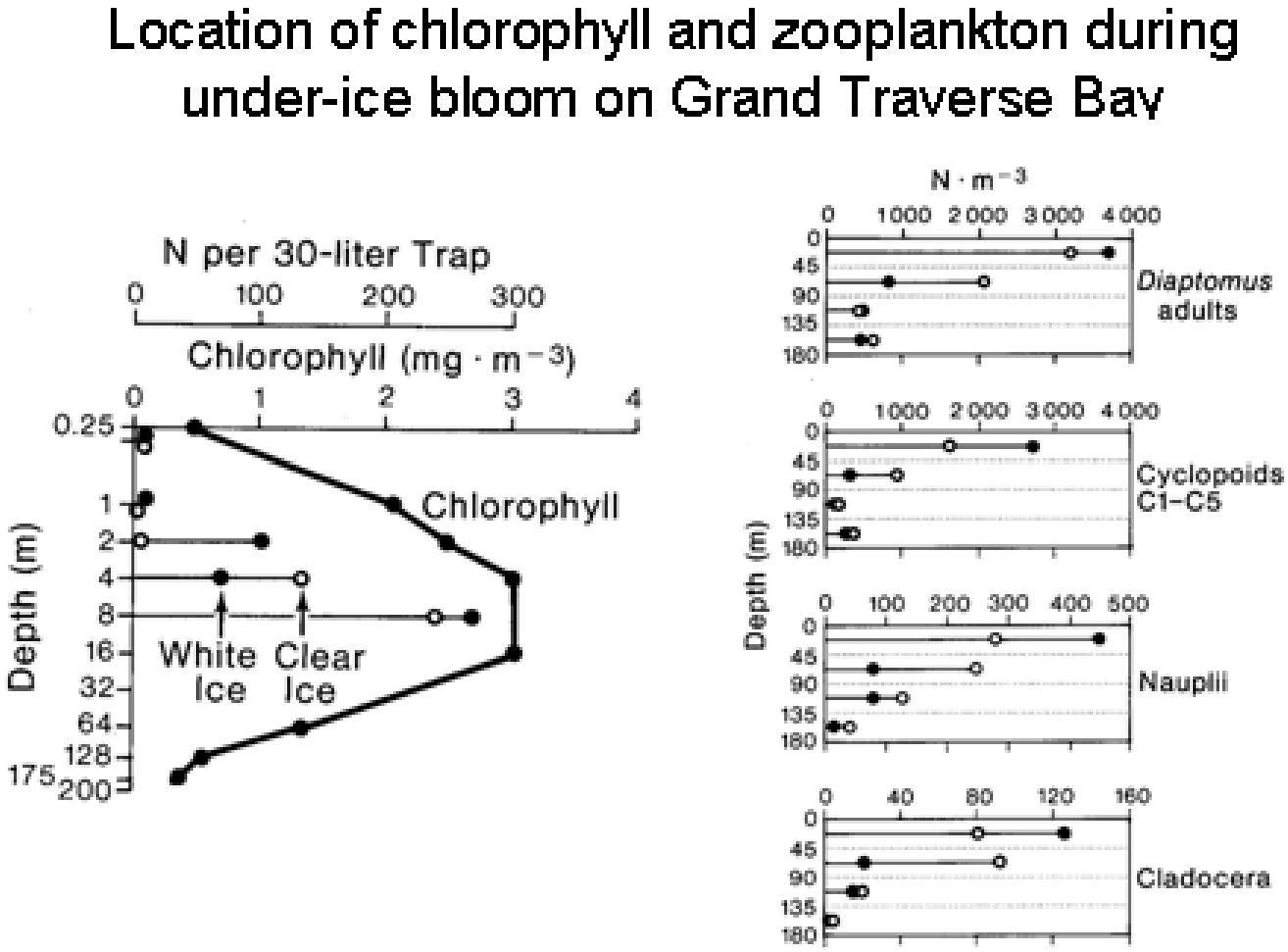
- Whitefish lay eggs in shallow water in winter
- Ice protects eggs from wave action
- Larval whitefish feed on copepodites and adult copepods during spring
- How does ice cover affect copepod production?

Under-ice Ecology & Climate



How much snow on the ice determines
Its transparency to light

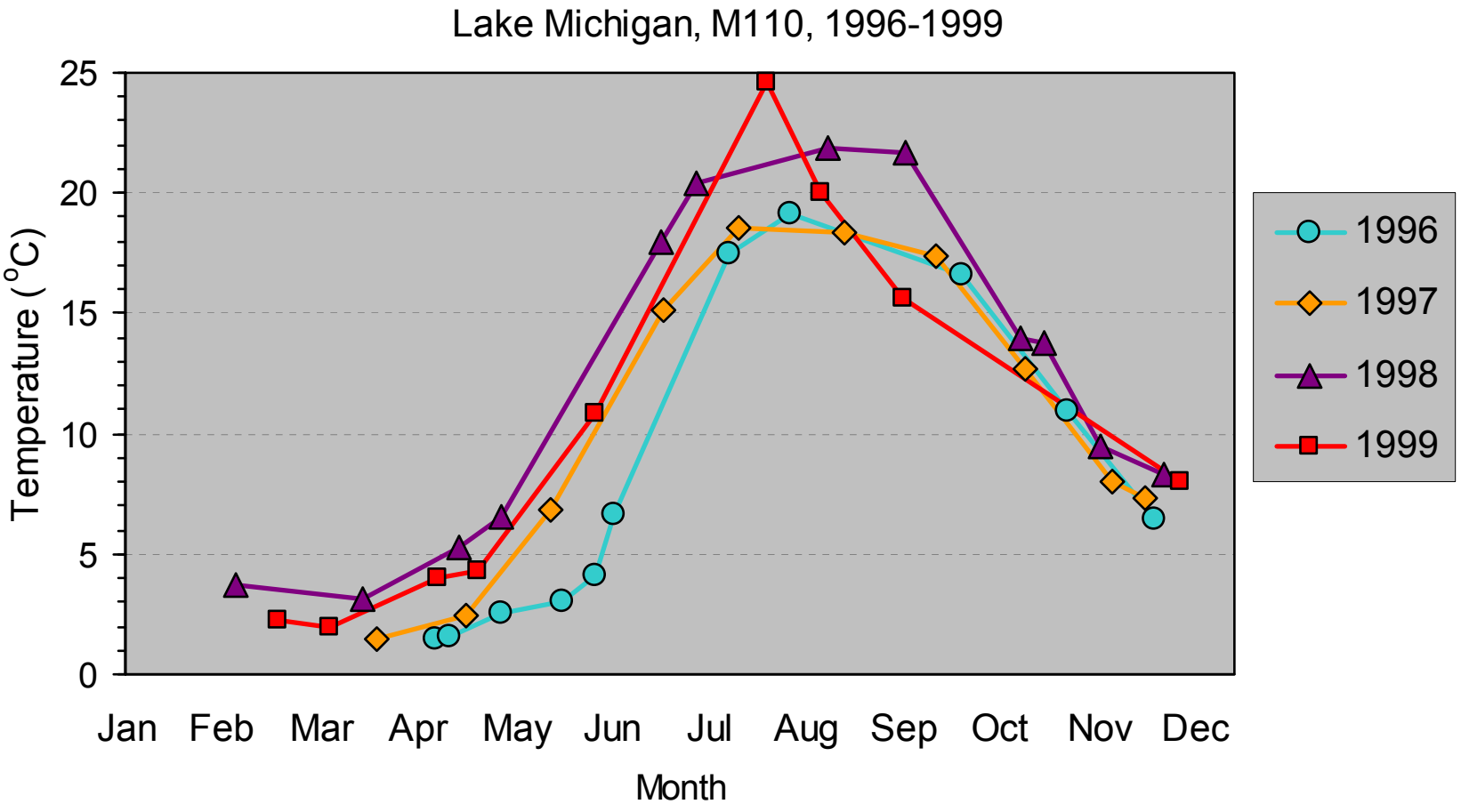
Zooplankton and chlorophyll distributions match during under-ice bloom



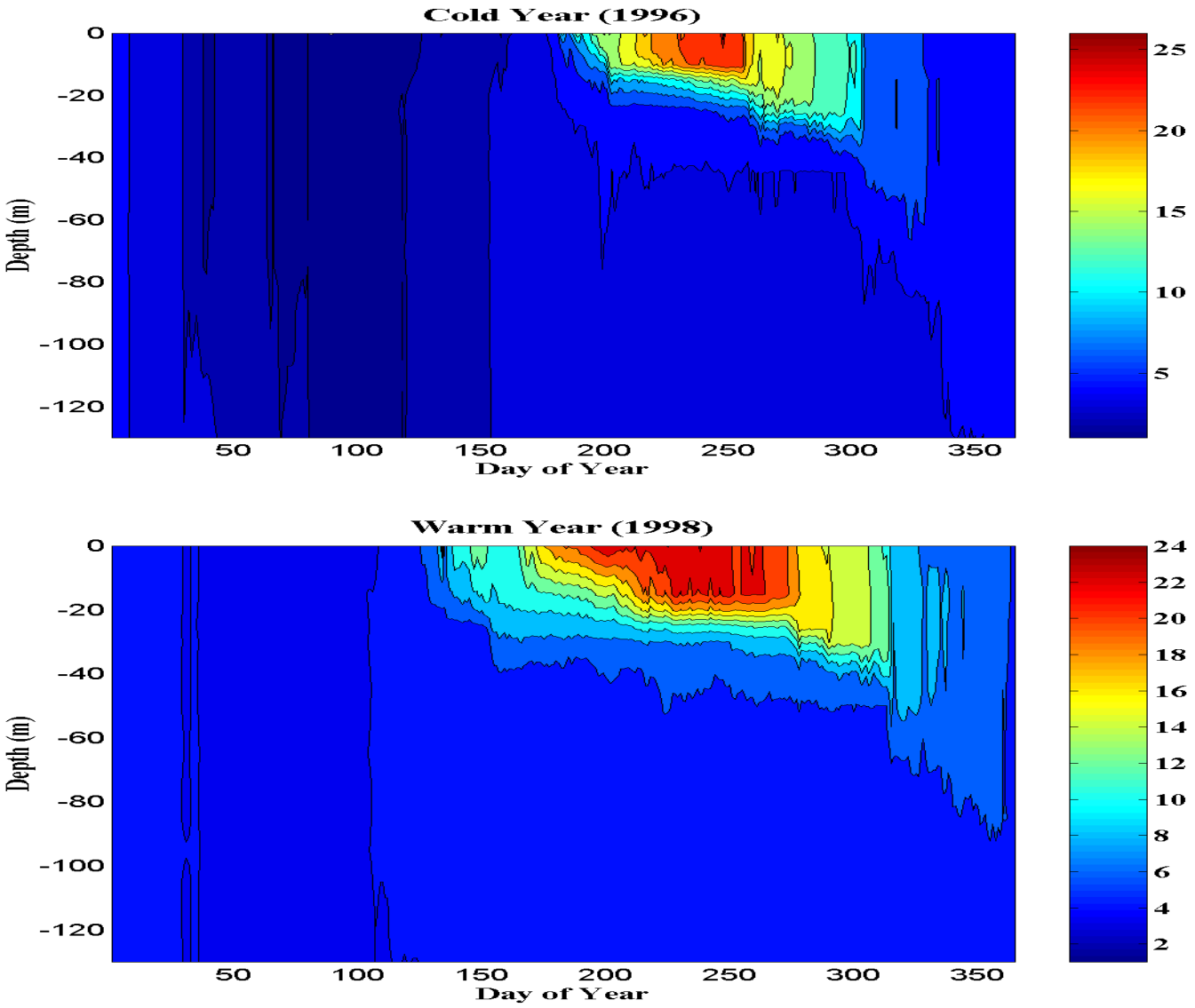
Alewife Recruitment

- Is there match/mismatch between (warm-water) alewife larvae and YOY with zooplankton in Lake Michigan?

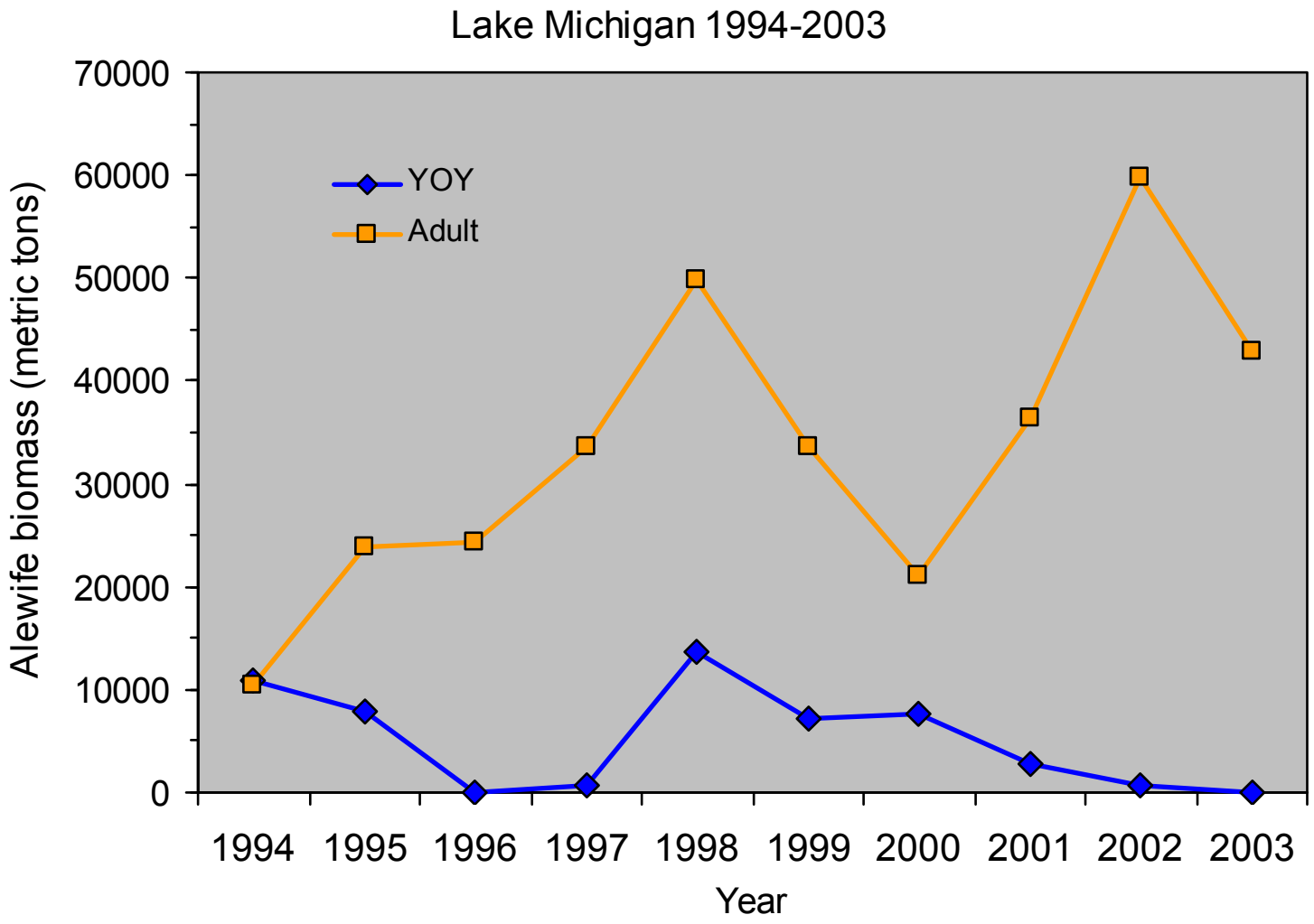
Interannual variability and climate signals: 1996 was one of coldest years and 1998 was warmest

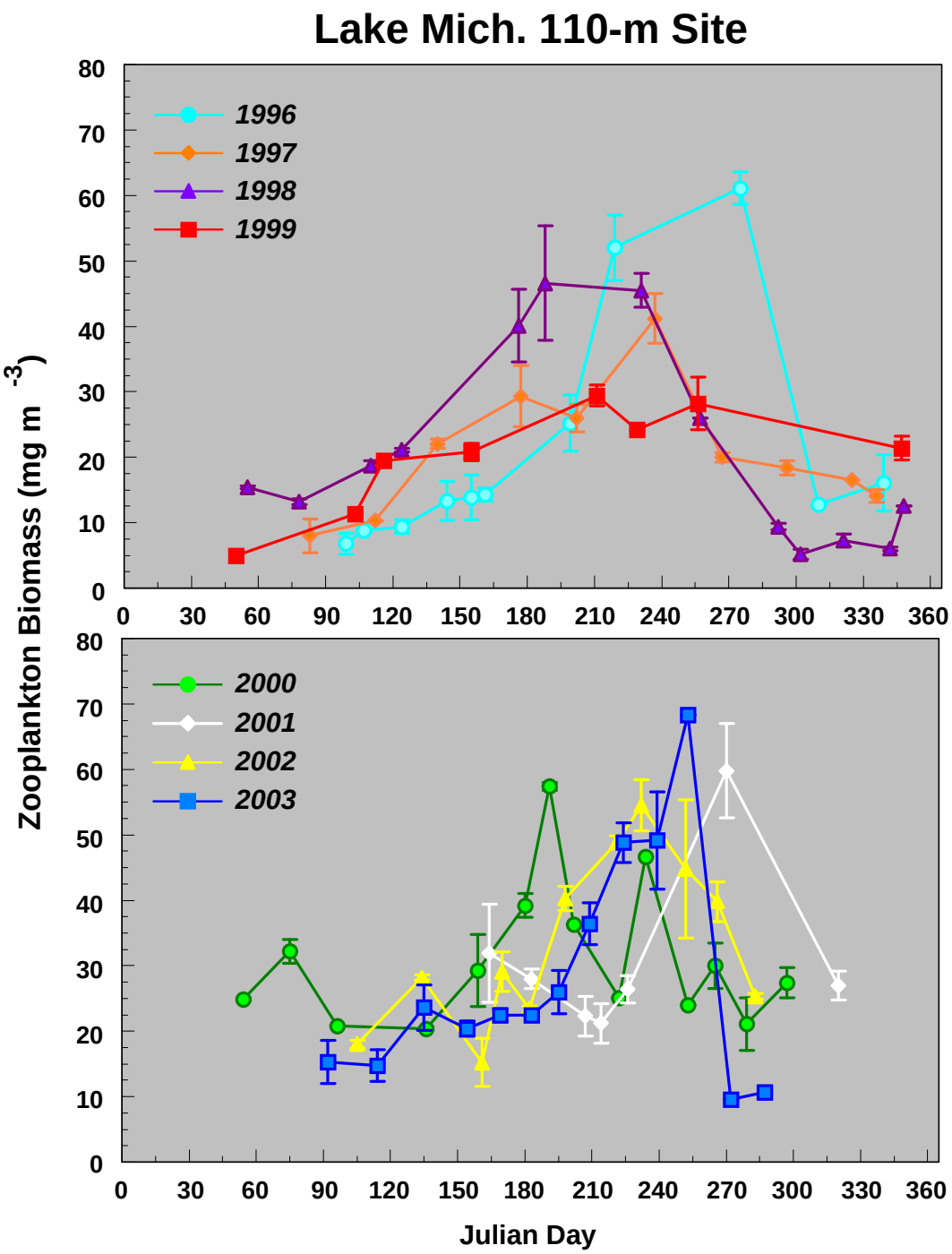


Mike McCormick's midlake thermistor chain

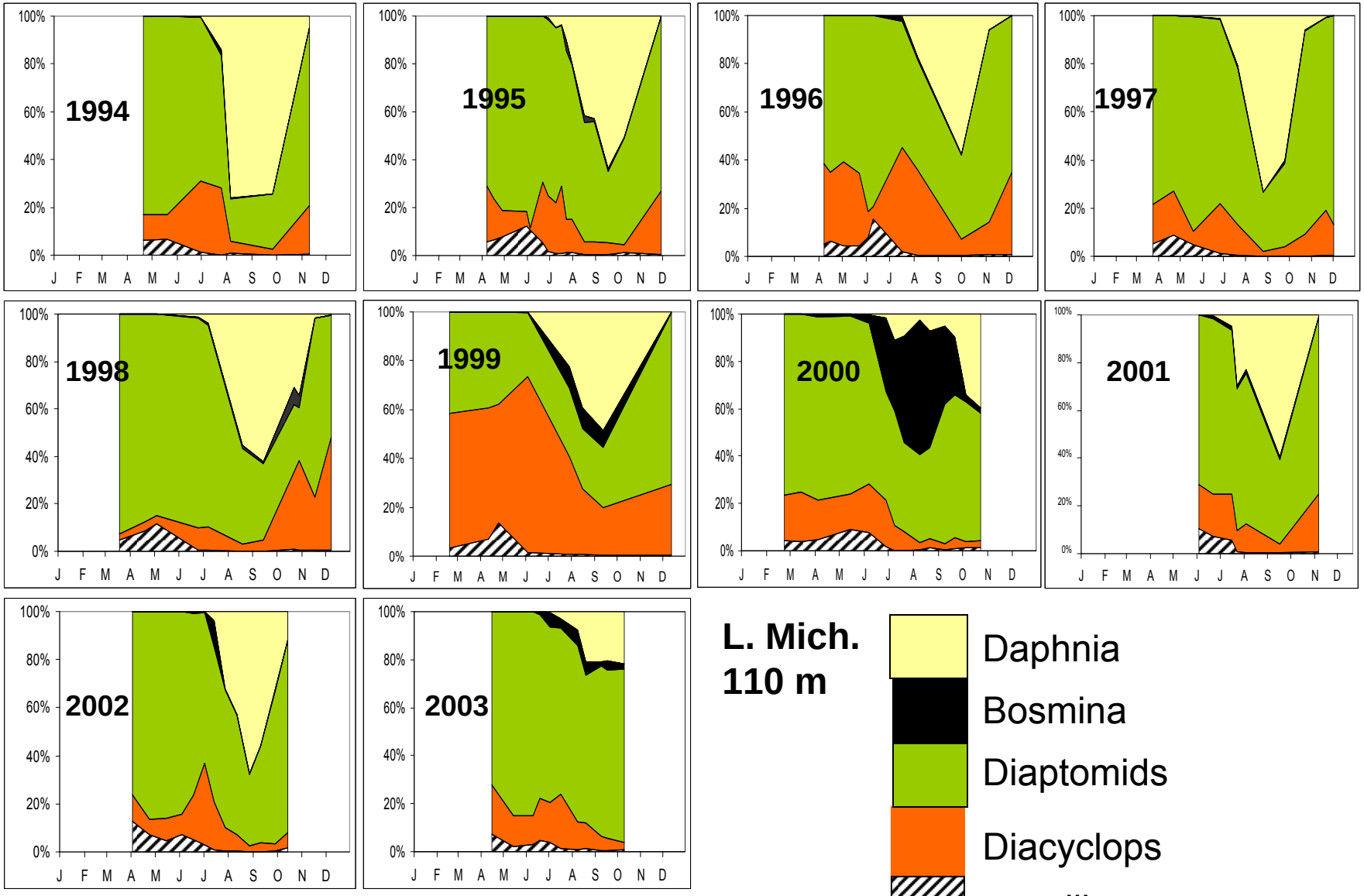


Alewife abundance in Lake Michigan estimated from bottom trawls: 1998 was the largest year class in 20-30 years.

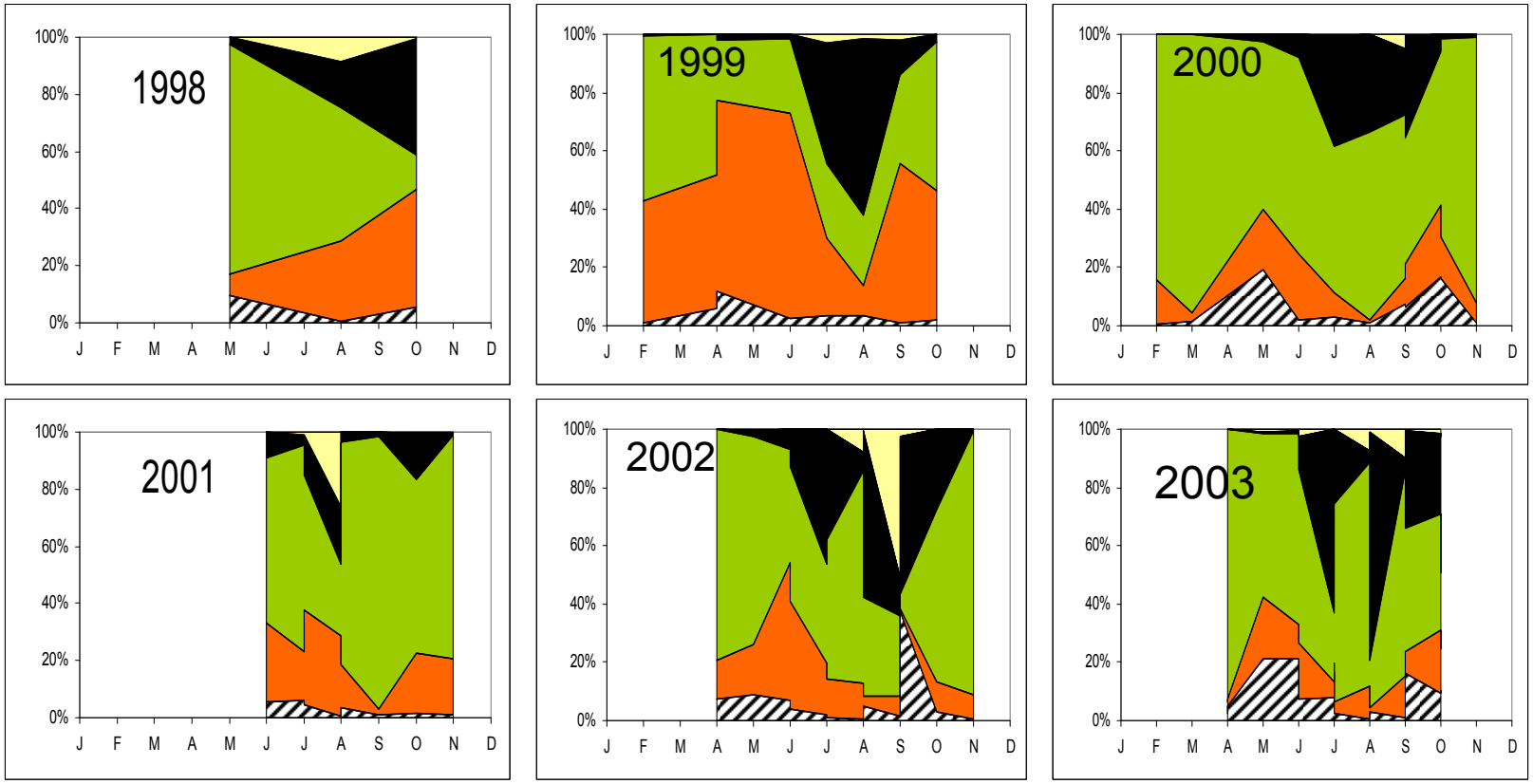



Lake Mich. 110-m Site
1996
1997
1998
1999
2000
2001
2002
2003
Zooplankton Biomass (mg m -3)
Julian Day
0
10
20
30
40
50
60
70
80
0
30
60
90
120
150
180
210
240
270
300
330
360

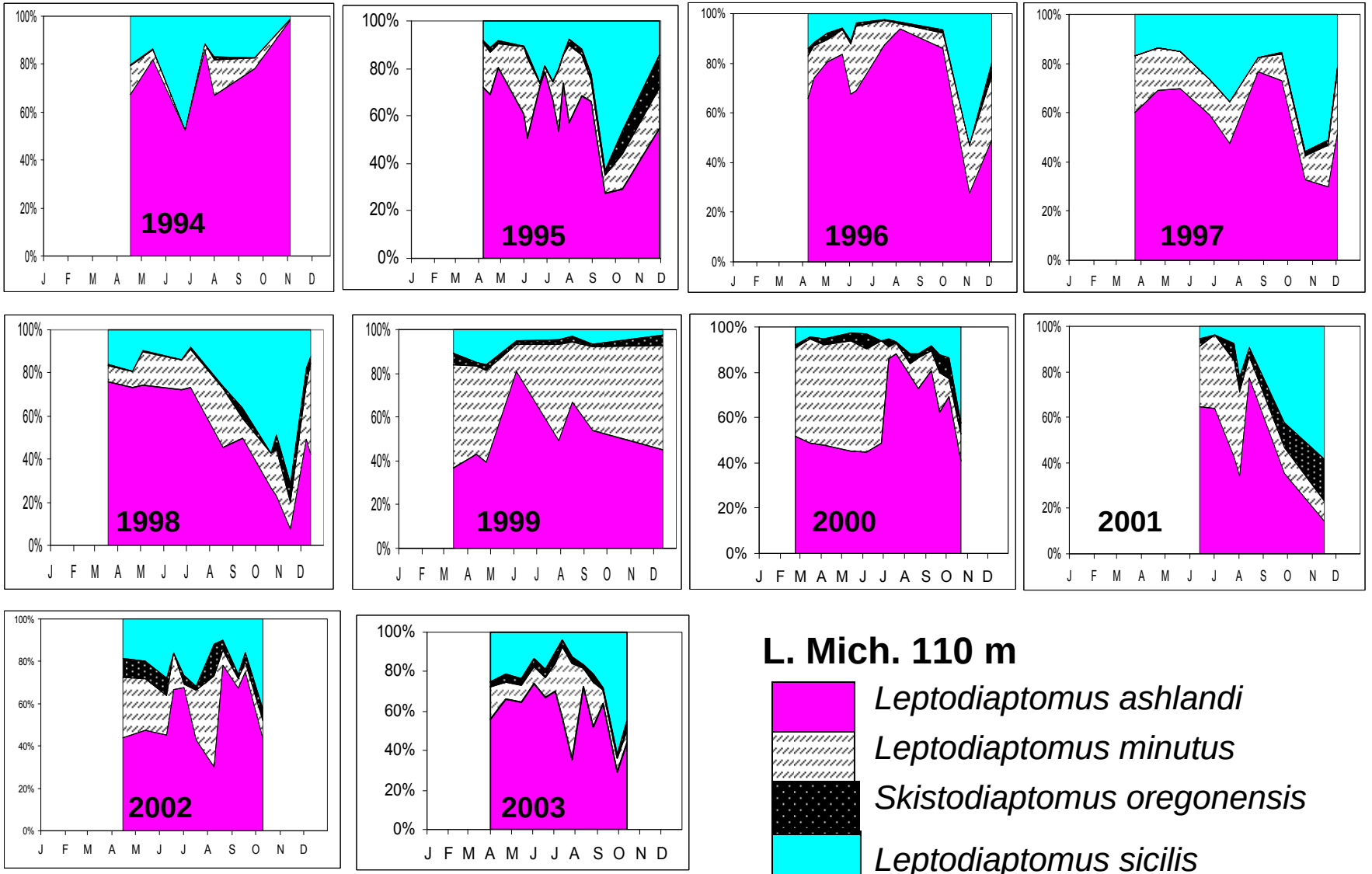
Lake Mich. 110-m Site % Zooplankton Biomass



L. Mich. 15-m Site % Zooplankton Biomass



L. Mich. 110-m Site Diaptomids % Composition

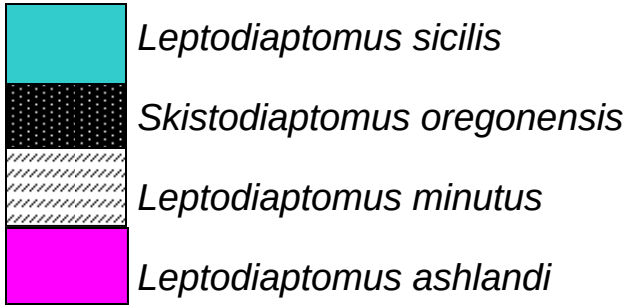


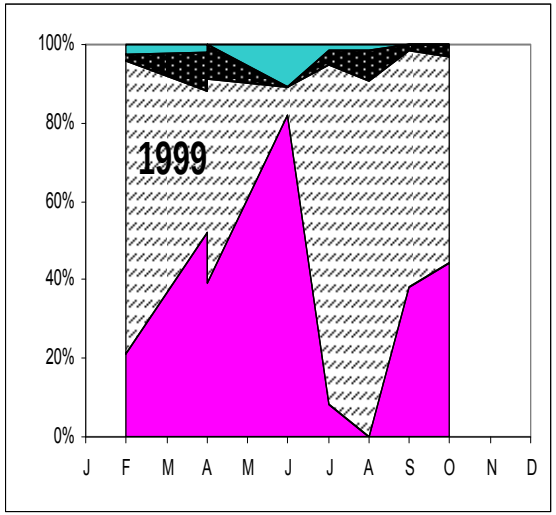
Month

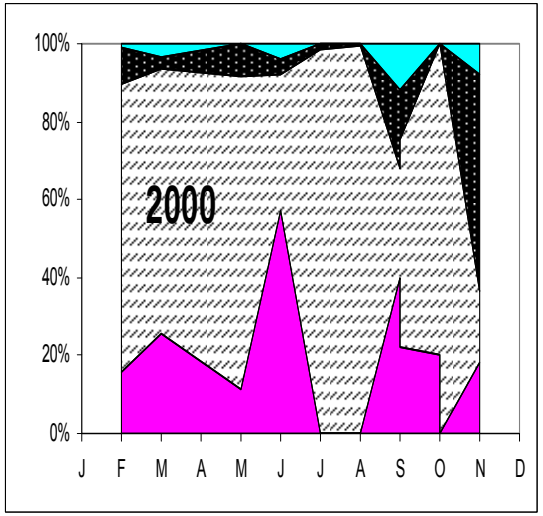
L. Mich. 110 m

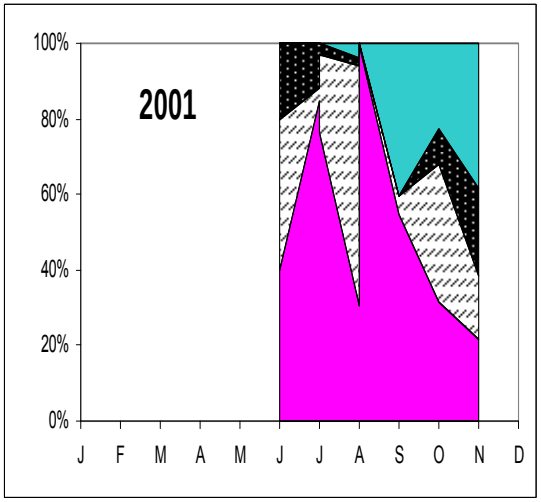
- *Leptodiaptomus ashlandi*
- *Leptodiaptomus minutus*
- *Skistodiaptomus oregonensis*
- *Leptodiaptomus sicilis*

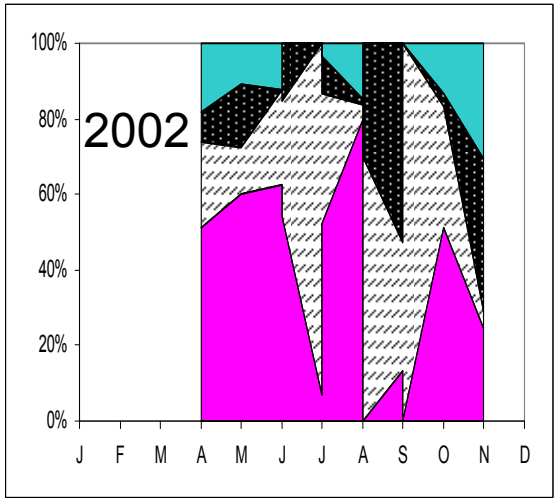
L. Mich. 15-m Site Diaptomids % Composition

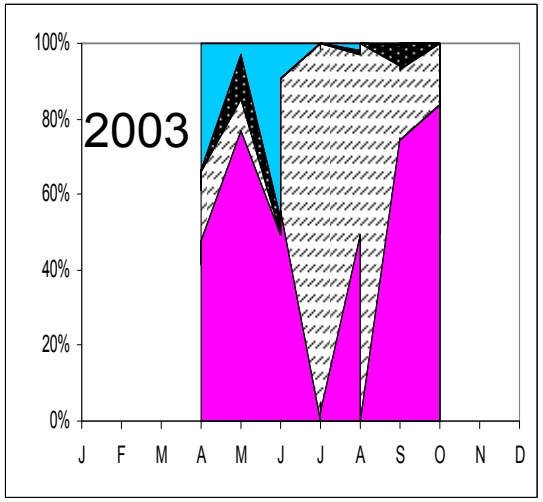












Month

Lake Erie dead zone—a weather/climate phenomenon?

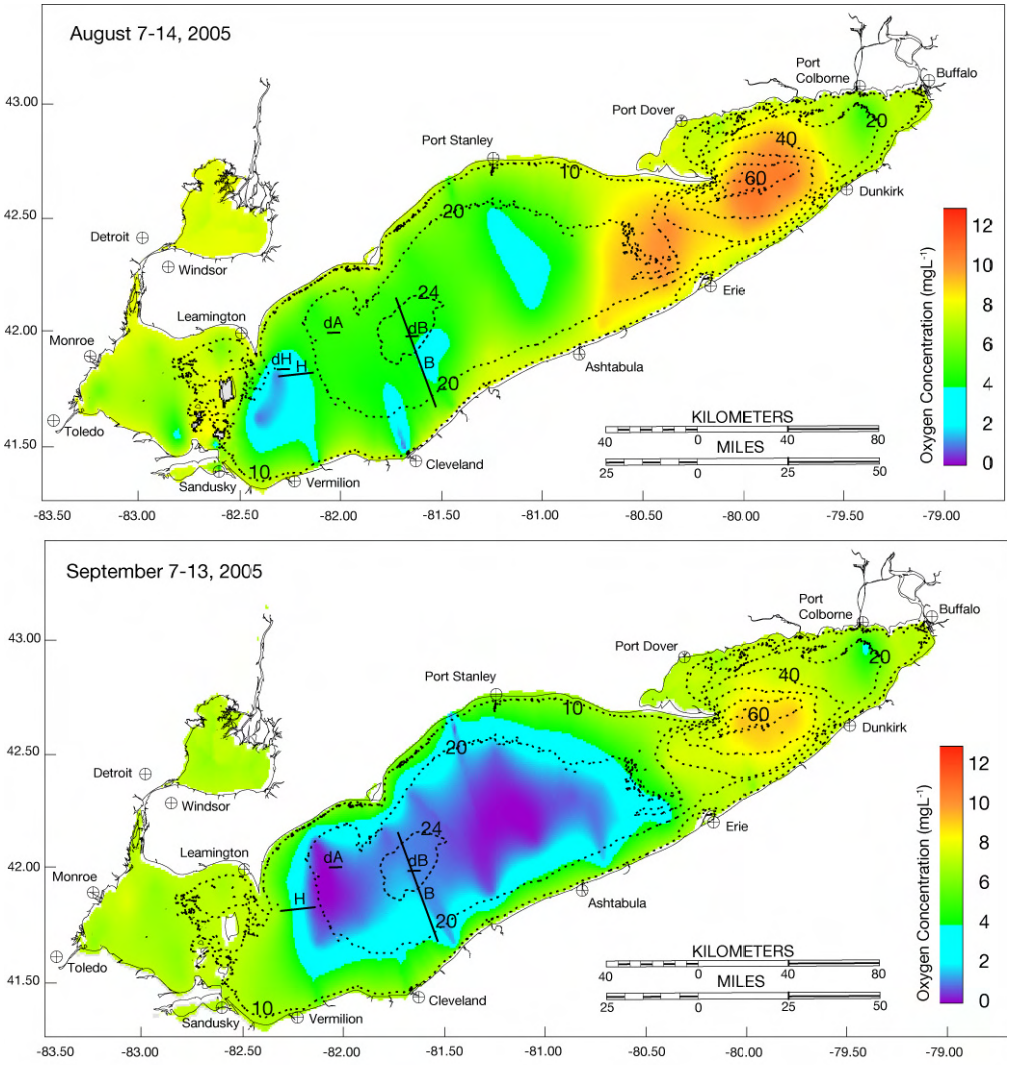
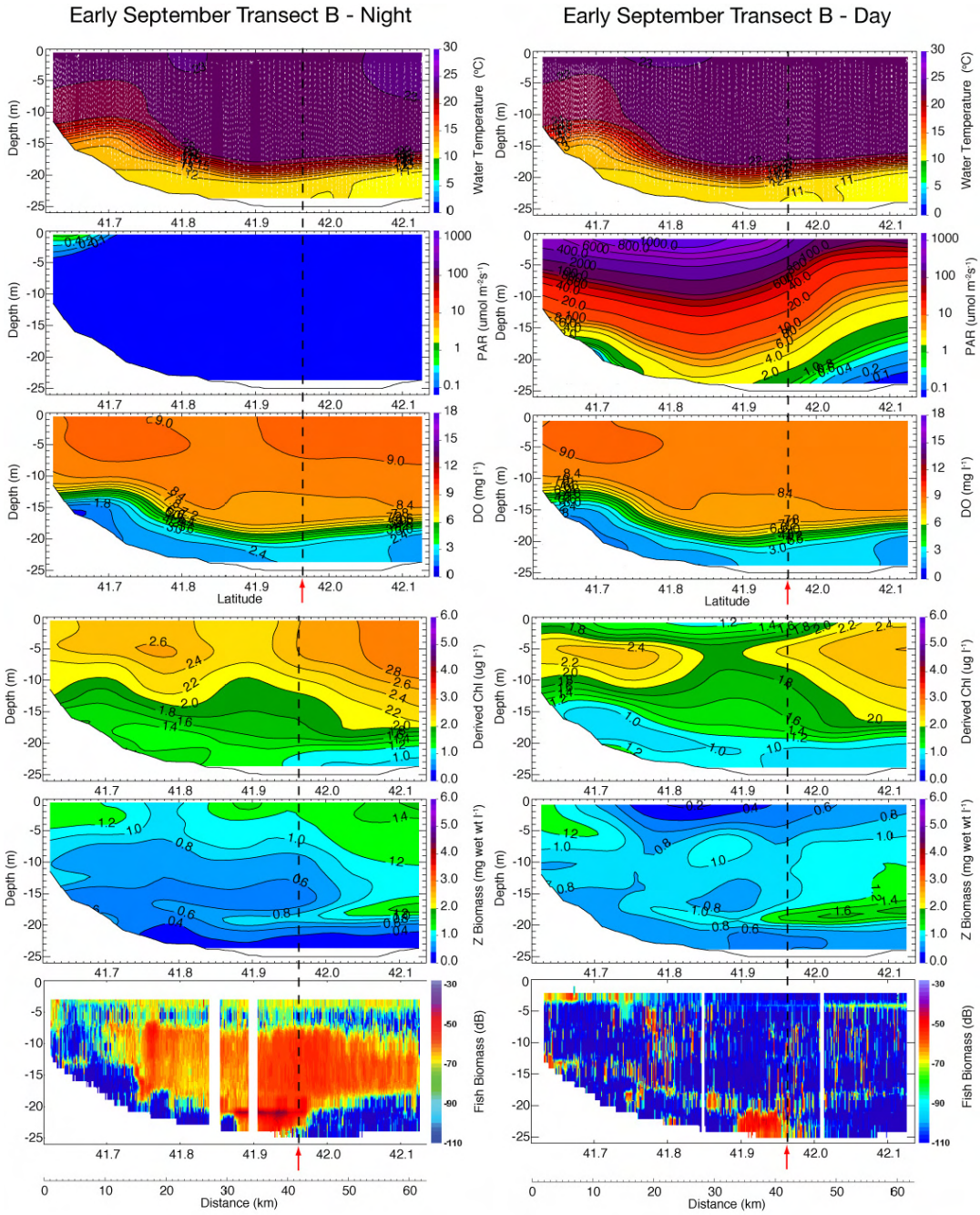


Figure 1.

A slice through Lake Erie with the plankton survey system and fisheries acoustics

Consequence:

- Hypoxia can alter match/mismatch between fish, zooplankton, and benthos as fish and zooplankton move to avoid hypoxic regions.



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